



Biokinetic Coefficients Determination for the Biological Treatment of Langat River

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ABSTRACT

River basin areas often associated with agriculture, industry and housing are the major source of pollution. This paper was conducted to determine biokinetic coefficients of pilot scale biofilm reactor. The biofilm reactor system (BRS) was installed on Langat River; Malaysia. The system was operated 65 days with different concentrations of mixed liquor suspended solid (MLSS), chemical oxygen demand (COD), and total suspended solids (TSS). Parameters in the influent and effluent of biofilm reactor were determined and biokinetic coefficients of maximum substrate utilization rate (K), half velocity constant (K_s), cell yield coefficients (Y), decay coefficient (K_d), and maximum specific growth rate (μ_{max}) were evaluated by Monod equations. Results showed that; the coefficients K , K_s , Y , K_d , and μ_{max} were 1.39 day^{-1} , 53.22 mg/L , 0.302 day^{-1} , 0.067 day^{-1} , and 1.936 day^{-1} . It can be concluded that, all coefficients were in the range of active sludge coefficients that are mentioned in the literature.

Keywords: Langat River, Activated Sludge Process, Biokinetic Coefficients. Monod equation.

1. INTRODUCTION

Biological treatment is the series of microorganism-based processes for water, wastewater and sludge treatment. The objectives of the biological treatment of domestic wastewater are to oxidize dissolved and particulate biodegradable matters into acceptable end products, to convert suspended and non-settleable colloidal solids into a biological floc or biofilm, to transform and remove nutrients, such as nitrogen and phosphorus, and in some cases, to remove specific inorganic constituents [1]. Activated sludge process is a commonly method and more effective of aerobic biological treatment systems and is designed on the basis of simplified hydraulic related parameters. But due to the wide variation in the composition of wastewater the designs based on hydraulic considerations are not sufficient to ensure efficient operation. So, it should be based on the kinetic approach [2].

Biokinetic coefficients are the basis of a wastewater treatment plant (WWTP) designing. Biokinetic coefficients used to control biological treatment processes and the models of the removal of organic matters and nutrients. Some of biokinetic coefficients are also used in WWTP operation, such as yield coefficient for calculating sludge production. These coefficients include maximum specific growth rate (μ_{\max}), maximum rate of substrate utilization per unit mass of microorganisms (k), half-velocity (saturation) constant, or substrate concentration at one-half of the maximum specific growth rate (K_s), cell yield (Y), and endogenous decay coefficient (k_d) [3].

There are several studies about biokinetic coefficient determination in different processes. crossflow membrane bioreactor processes (CF-MBR) in the treatment of refinery wastewater was studied by [4]. They operated bioreactor under two mixed liquor suspended solids (MLSS) values of 3000 and 5000 mg/L. Hydraulic retention time (HRT) values were changed and biokinetic coefficients in each MLSS were calculated. The values of biokinetic coefficients were within the normal range of the activated sludge process found in the literature, except the values of Y . Other group of research [4] determined biokinetic coefficients for activated sludge processes such as conventional, extended aeration, and contact stabilization on municipal wastewater. Their investigation showed that the yield coefficient (Y), decay coefficient (k_d), maximum specific growth rate, and saturation constant (K_s) for conventional and contact stabilization processes were in the approved range. However, in the extended aeration process, values of K_s and Y in MLSS of 5000 mg/L were out of ranges [5] evaluated biokinetic parameters in municipal wastewater treatment with a submerged membrane reactor by the monod equation. Their result showed that Y , k_d , K_s and μ_{\max} coefficients were 0.67 mgVSS/mg, sCOD, 0.5 day⁻¹, 65.5 mg/L and 1.86 day⁻¹, respectively. Recently, another group [4] conducted a study to determine biokinetic coefficients of a pilot-scale adsorption-bio-oxidation process. The coefficients Y , K_d , K_s , and μ_{\max} of A-stage were 1.34 mg VSS/mg sCOD, 0.17 day⁻¹, 8.61 mg/L, and 2.78 day⁻¹, respectively. Also, Y , K_d , K_s , and μ_{\max} of B-stage were 0.74 mg VSS/mg sCOD, 0.12 day⁻¹, 3.34 mg/L, and 71.94 day⁻¹, respectively. They conclude that, All coefficients were in the range of activated sludge coefficients that are mentioned in the literature, except μ_{\max} and K_s of B-stage. However, K_s value of B-stage was close to the desired range. Table 1 outlines the previous reported work regarding BioKinetic coefficients evaluation with different treatment systems.

Mathematical models describe the interaction between the growth of microorganisms and utilization of the growth limiting substrate in activated sludge processes are based on Monod model, which is considered as the most commonly and widely used for determining the biokinetic coefficients. In continuous-flow and completely-mixed reactor, determination of the biokinetic coefficients is usually achieved by collecting data from lab-scale or pilot-scale experimental setups operated at various hydraulic retention times (HRT) [11].

The main purpose of this study was the determination of biokinetic coefficients for activated sludge processes using Monod kinetics model. These coefficients are maximum substrate utilization rate (K), half velocity constant (K_s), cell yield coefficients (Y), decay coefficient (K_d), and maximum specific growth rate (μ_{\max}).

Table 1 BioKinetic coefficients obtained from different studies

Treatment system	K_d	μ_m	K_s	Y	K	References
Assimilable Organic Carbon	-	16.4	1.68E+4	-	8.1	[6]
Biological Aerated Filter	-	10.75	39.44	0.39	-	[7]
Up Flow Anaerobic Sludge Blanket	0.02	0.28 - 0.04	51.7 - 71.8	0.3 - 0.4	-	[8]
Biological nutrient removal	-	2.9	25	0.49	-	[9]
Moving fixed bed biofilm reactor	0.05	0.7	1.21	0.18	0.05	[10]

2.

MATERIALS AND METHODS

2.1 Description of the system setup

The laboratory-scale-reactor that has been employed in this investigation is shown in Figure 1. It was made out of glass with a height of 120 cm, a diameter of 60 cm. The examined polluted river water (langat river) was fed to the reactor via a pump (1) to ensure regularity of the flow. The capacity of the aeration tank (3) was 290 liters. The reactor was operated at ambient temperature, $22 \pm 2^\circ\text{C}$. It was packed with a media of 80 particles with a particle size of 0.25-2.00 mm and a mean diameter of 1.30 mm. Before feeding the water to the reactor, water was withdrawn from the river and let to settle down in a primary sedimentation tank (2). The outlet of the reactor was opened to drain the liquid via valve V₄. Although nearly 20 liters were kept in the reactor along with the granular activated carbon (GAC) media. Afterwards, the outlet valve was closed. Later, wastewater coming from Langat River was fed to the reactor. For providing and maintaining aerobic conditions in the reactor, stone air diffusers were fixed in the bottom of basins. Samples of 100 ml of wastewater were then collected through valve V₄ and analyzed.

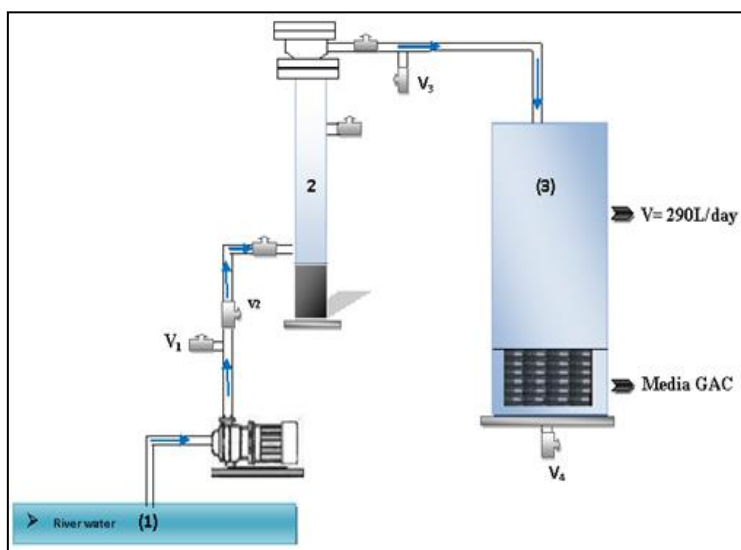


Figure 1 Biofim Reactor

2.2 Langat River Characterization:

Table 2 shows average values influent and effluent concentration for characteristics of Langat River through the working period.

Table 2. Characteristics of Langat River

HRT	COD		TSS		Flow rate (L/hr)
(hrs)	Influent	Effluent	Influent	Effluent	
HRT 4	78.15	23.45	80.49	24.65	73.6
HRT 6	93.45	28.05	90.09	23.21	49.2
HRT 2	88.2	26.13	88	26.54	145

2.3 Analytical Method:

Samples were taken from Langat River. It was collecting six days a week from the chosen place by using pump. Influent samples and effluent samples analyzed for measuring soluble COD and TSS. Table 3 presents the collected data used to evaluate biokinetic coefficients by monod model equations. These data was extracted from our previous published work[12]. All analyzes were done in accordance with the standard methods.

Table 3. Mean values of data for biokinetic coefficients

Days	S ₀ (mg/L)	S(mg/L)	MLSS (mg/L)	X _e (mgTSS/L)	Xθ
15	74	22	3476	27	54
16	84	25	4063	24	48
20	69	21	4468	27	54
22	83	23	4956	27	54
23	94	24	5086	33	66
25	80	27	4988.13	22.5	45
32	97	32	6048	12.2	45
33	88	24	6236	23	24.2
34	96	31	6448.65	16	32
40	83	30	6690	17.07	34.14

Equation 1 was used to find k and K_s , while Y and K_d were evaluated by equation 2, and equation 3 used to determine μ_{\max} .

$$\frac{X\theta}{S_0 - S} = \frac{K_s}{K} \frac{1}{S} + \frac{1}{K} \quad (1)$$

$$\frac{1}{\theta} = Y \frac{S_0 - S}{X\theta} - K_d \quad (2)$$

$$\theta = \frac{1}{\mu_{\max}} + \frac{K}{\mu_{\max}} \frac{(S_0 - S)}{S} \quad (3)$$

Where,

k = Maximum rate of substrate utilization per unit mass of microorganisms, day⁻¹

K_d = Endogenous decay coefficient, day⁻¹

K_s = Half velocity constant, substrate concentration at one-half of the maximum growth rate, mass/unit volume

Y = Cell yield coefficient, mg/mg (defined as the ratio of the mass of cells

μ_{\max} = the maximum specific growth rate, day⁻¹

S_0 : Influent substrate concentration, mg COD/L.

S : Effluent substrate concentration, mg COD/L.

X: Biomass concentration, mg TSS/L.

θ : hydraulic retention time, day

3. RESULTS AND DISCUSSION:

The reactor was operated at three hydraulic retention times (HRT) for about 65 days of operation. From the experimental results, the biokinetic coefficients obtained using the Monod model. It describes the relationship between the growth rate and substrate concentration using the maximum possible growth rate. Based on equation 1, biokinetic coefficients K_s and k were determined from the experimental results by plotting a graph of $\frac{X\theta}{S_0 - S}$ versus $\frac{1}{S}$ as shown in Figure 2. K value is employed to find out the volume of biological reactors. Greater is the value of k , smaller will be the size of reactor. K_s has no direct application in process design. It only gives an idea about the change in the specific growth rate with a change in the concentration of the growth limiting substrate [2]. A linear regression line was fitted to the plotted data. Intercept on the y-axis and the slope of this line were used to find k and K_s . The equation of the fitted line is also shown on the graph. From the linearized Equation and Figure 2, the coefficients K and K_s , were found to be 1.39 day^{-1} and 53.22 mg/L , respectively. The value of maximum rate of substrate utilization per unit mass of microorganisms (k) obtained in this study falls within the general range of $2\text{-}10 \text{ day}^{-1}$ (as presents in Table 3) for wastewater treatment reported by [13]. Value of 3.125 day^{-1} was reported for tannery wastewater. While a value as low as 0.216 day^{-1} was reported for fertilizer industry wastewater by [14]. These variations may be attributed to the characteristics nature of the various wastewaters studied.

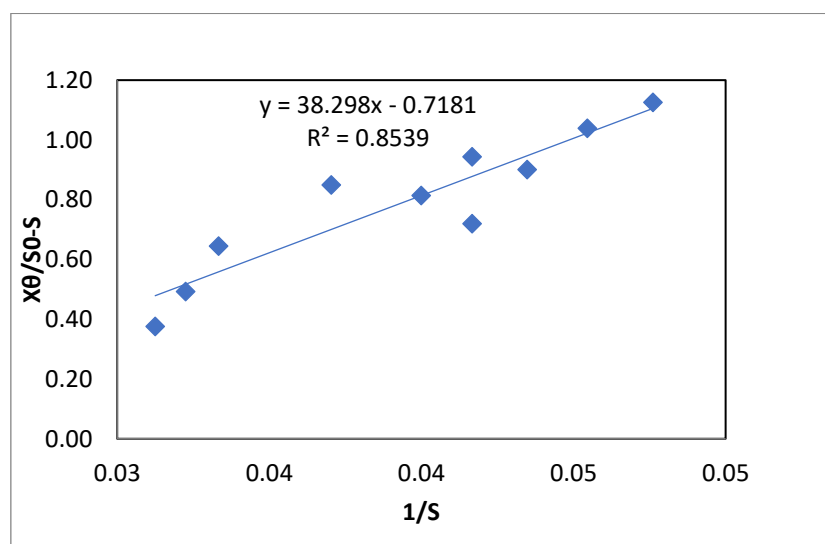


Figure 2 Determination of K_s and K

On the other hand, half velocity constant K_s was obtained as 53.22 mg/L in the present study which is large compare to 39.44 mg/l obtained by [7]. This high value is an indication that the process yield occurred at higher substrate concentration. However, K_s has no direct

application in the process design, its significance is of theoretical nature and gives an idea about change in specific growth rate with more a change in the concentration of growth limiting substrate.

According to experimental data, equation 2 can be used to estimate the k_d and Y values by plotting a linear regression of $\frac{1}{\theta}$ against $\frac{S_0 - S}{X\theta}$. Endogenous decay coefficient k_d represents the fraction of the cells oxidized by endogenous respiration per unit of time. While Yield Coefficient Y or Biomass Yield is the mass of cells produced per unit of substrate utilized. It may also be described as how biomass is produced against substrate utilized. The intercept from the equation line is equal to k_d whereas Y is the slope of the straight line that passes through the plotted points. Therefore, Endogenous Decay Constant (K_d) and Yield Coefficient (Y) of 0.0028 and 0.5083 respectively were obtained in this study as shown in Figure (3).

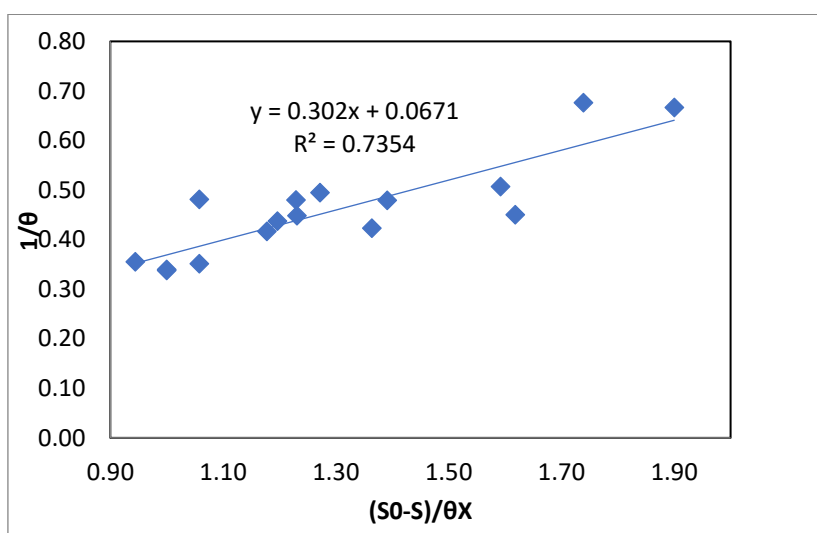


Figure 3 Plot for the Determination of Y and K_d

The very low value of K_d obtained in this study is an indication of low decay rate and also shows that there is a very higher production of excess sludge in the process. On the other hand the yield coefficient, Y was observed to be in the normal range as given in Table 3. It is noted that, Kinetic parameters vary for different industrial wastewater based on the nature of raw materials processed and the nature of wastewater effluent.

Maximum specific growth rate (μ_{max}) of BRS was estimated using equation 3 and Figure 4. According to Figure 4 was plotted with the x-axis $(S_0 - S)/S$ and θ along y-axis and a linear regression line was fitted to the plotted data. Intercept on the y-axis ($1/\mu_{max}$) was used to find μ_{max} and the slope of this line (K/μ_{max}) was used to find it. Value of μ_{max} in this study was obtained to be 1.936 day⁻¹ which considered within the reported values range for the conventional activated sludge processes of Metcalf and Eddy presented in Table 3.

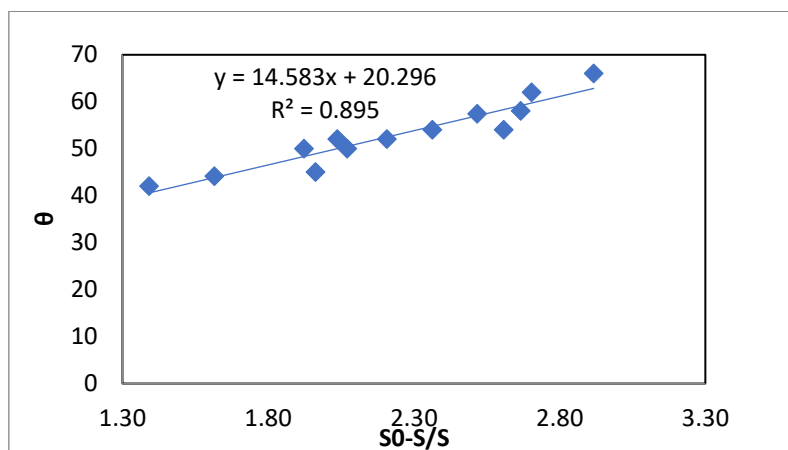


Figure 4 Plot for the Determination of μ_{max}

Table 3. BioKinetic coefficients for Langat River.

Kinetic coefficients	Range (Metcalf and Eddy (1991))	Values of this study	Units
k	2 - 10	1.39	Day ⁻¹
K _s	10 - 60	53.22	mg of substrate / L
Y	0.3 - 0.6	0.302	(dimensionless)
μ_{max}	0.6 - 6	1.936	Day ⁻¹
K _d	0.025- 0.075	0.067	Day ⁻¹

4. CONCLUSION:

The biokinetic coefficients k(maximum substrate utilization rate),K_s (half velocity constant), Y(cell yield coefficient), K_d (decay coefficient) and μ_{max} (and maximum specific growth rate) were found to be 1.39 day⁻¹, 52.22 mg/L, 0.302 day⁻¹,0.067 day⁻¹, and 1.936day⁻¹, respectively. All coefficients were in the range of activated sludge coefficients that are mentioned in the literature. From this study, R² values of regression model were in the range of 0.7-0.9 which indicate satisfy fit to the data. It can be conclude that, the kinetic coefficients in various studies are very different for different kinds of industrial effluents. Even in similar studies, the coefficients are slightly different based on the quality of input wastewater and the kind of treatment system and the difference results from operating conditions and changing quality of input substrate and their changes.

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تحديد المعاملات الحركية الحيوية للمعالجة البيولوجية لنهر لانغات

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ملخص البحث:

تعد مناطق أحواض الأنهار المرتبطة في كثير من الأحيان بالزراعة والصناعة والإسكان هي المصدر الرئيسي للتلوث. أجريت هذه الورقة لتحديد المعاملات الحركية الحيوية لمفاعل بيو فيلم على نطاق تجريبي. تم تركيب نظام مفاعل بيو فيلم (BRS) على نهر لانغات ؛ ماليزيا. تم تشغيل النظام 65 يوماً مع تركيزات مختلفة من المواد الصلبة العالقة في الحمأة النشطة (MLSS)، ومتطلب الأكسجين الكيميائي (COD)، و تحديد إجمالي المواد الصلبة المعلقة (TSS) في السائل والنفايات السائلة لمفاعل بيو فيلم وتم تحديد معاملات الحركة الحيوية لأقصى معدل استخدام الركيزة القصوى (K)، وثابت السرعة النصفية (K_s)، ومعامل إنتاج الخلية (Y)، ومعامل الاضمحلال (K_d)، والحد الأعلى لمعدل النمو (μ_{max}). وقد أظهرت النتائج ذلك؛ وكانت المعاملات K_s، Y، K_d، و μ_{max} : 1.39 يوم⁻¹، 53.22 ملغرام /لتر، 0.302 يوم⁻¹، 0.067 يوم⁻¹، و 1.936 يوم⁻¹. نستنتج أن جميع المعاملات كانت في نطاق معاملات الحمأة النشطة المذكورة في الأدبيات.

الكلمات المفتاحية: نهر لانغات، عملية الحمأة المفعلة، معاملات الحركة الحيوية، معادلة موند.